Active Control of High-Frequency Combustor Instability Demonstrated

To reduce the environmental impact of aerospace propulsion systems, extensive research is being done in the development of lean-burning (low fuel-to-air ratio) combustors that can reduce emissions throughout the mission cycle. However, these lean-burning combustors have an increased susceptibility to thermoacoustic instabilities-high-pressure oscillations much like sound waves that can cause severe high-frequency vibrations in the combustor. These pressure waves can fatigue the combustor components and even the downstream turbine blades. This can significantly decrease the combustor and turbine safe operating life. Thus, suppression of the thermoacoustic combustor instabilities is an enabling technology for lean, low-emissions combustors. Under the Propulsion and Power Program, the NASA Glenn Research Center in partnership with Pratt & Whitney, United Technologies Research Center, and Georgia Institute of Technology is developing technologies for the active control of combustion instabilities.

With active combustion control, fuel pulses are used to put pressure oscillations into the system. These oscillations, in turn, cancel out the pressure oscillations being produced by the instabilities. Thus, the engine can have lower pollutant emissions as well as long life.

The use of active combustion instability control to reduce thermoacoustic-driven combustor pressure oscillations was demonstrated for a high-frequency (530-Hz) instability on a single-nozzle combustor rig at United Technologies Research Center. This is the first known successful demonstration of high-frequency combustion instability suppression in a realistic aircraft engine environment. This rig, which emulates an actual engine instability experience, has many of the complexities of a real engine combustor (i.e., actual fuel nozzle and swirler, dilution cooling, etc.).

High-frequency fuel valve characterization rig.

Long description of figure 1 This figure shows a research rig that is used to determine the dynamic characteristics of a high-frequency fuel valve. The rig, which is contained in a single-wide instrument rack, contains a fluid pump, accumulator chamber, and plumbing to force pressurized fluid through the valve under test. The valve is mounted about midway up the rig.

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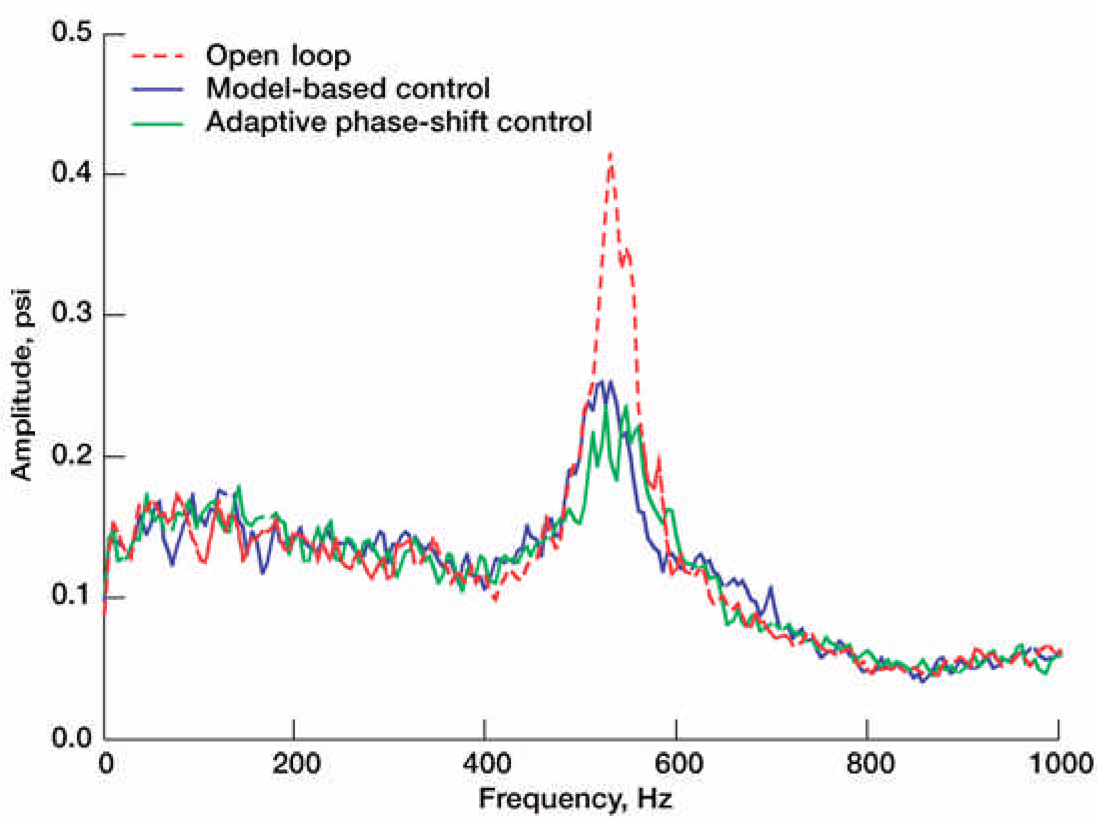
A fuel-delivery system that is based on a high-frequency fuel valve from the Georgia Institute of Technology and that can pulse the fuel at the 530-Hz instability frequency was modeled, developed, and tested in a valve characterization rig assembled for this purpose (see the preceding photograph). Because of the high frequency and low amplitude of the instability relative to the background combustor noise (see the following graph), sophisticated control algorithms were developed that (1) identify the instability frequency from the noise and (2) apply fuel pulsations at the correct frequency and phase to reduce the instability. A model-based control method and an adaptive phase-shifting control method were both shown to reduce the pressure oscillations at the instability frequency (see the graph). Work is continuing to apply these advanced control methods to future low-emission combustor concepts.



Amplitude spectra of the combustor pressure oscillations without instability control, with model-based instability control, and with adaptive phase-shifting instability control.

Long description of figure 2 This figure shows the amplitude spectra of the combustor pressure with the uncontrolled combustion instability. The combustion instability shows a peak in the spectra at about 530 Hz. The peak is at about 0.3 psi. The surrounding noise at other frequencies is at about 0.15 psi. The figure also shows the combustion instability amplitude spectra when being controlled by a model-based instability control method and by an adaptive phase-shifting control method. The peak using both control methods has been reduced to about 0.2 psi.

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Find out more about this research:
Active combustion control
http://www.grc.nasa.gov/WWW/cdtb/projects/combustor/
Glenn's Combustion Branch http://www.grc.nasa.gov/WWW/combustion/

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